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MEMORANDUM

EXPLORATORY INVESTIGATION OF AERODYNAMIC FLAMEHOLDERS

FOR AFTERBURNER APPLICATION

By Helmut F. Butze and Allen J. Metzler

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Cleveland, Ohio

NATIONAL AERONAUTICS AND
SPACE ADMINISTRATION
WASHINGTON
May 1959

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SUMMARY

An investigation was conducted to determine the flameholding capabilities of aerodynamic jets at afterburner operating conditions. Stability data for a number of aerodynamic flameholders were obtained in a 5- by 5-inch test section at inlet-air reference velocities up to 600 feet per second, an inlet-air temperature of 1250° F, and a combustor-inlet pressure of 15 inches of mercury absolute. Combustion efficiency and stability data of the more promising combinations were then obtained in a 10- by 12-inch test section at the same test conditions. Both air and stoichiometric mixtures of fuel and air were used in the jets; mixture flow rates were approximately 1 percent by weight of the total airflow rate. Injection pressures were limited to values that might be available from compressor-bleed air.

At a reference velocity of 600 feet per second, aerodynamic flameholders alone were unable to maintain a stable flame at injection pressures up to 70 pounds per square inch; large reductions in velocity were required to achieve flame stabilization. When the aerodynamic jets were used in combination with a V-gutter flameholder with approximately a 30 percent blocked area, flame stabilization was attained at a velocity of 600 feet per second; however, the combustion efficiencies of the various combinations were no greater than that obtained with the V-gutter alone.

INTRODUCTION

Stabilization of flames in ramjets and afterburners is generally accomplished by means of bluff-body flameholders. Recently, a number of experiments were reported in the literature (refs. 1 to 4) whereby flames were stabilized solely by means of aerodynamic jets, directed either contrastream or at right angles to the main flow. However, practically all the experiments reported in the literature were subject to one or more of the following limitations: (a) They were obtained in small-scale apparatus such as 2-inch-diameter tubes, (b) test conditions were generally far less severe than those encountered in afterburner operation, and (c) often only stability data were obtained, but no combustion-efficiency data.

The research program presented in this report was initiated to investigate the performance of aerodynamic flameholders at conditions more representative of actual afterburner operation; flow rates and injection pressures of jet air generally did not exceed values that might be available from compressor-bleed air. Two test rigs were employed to obtain combustion efficiency and stability data for a number of aerodynamic flameholder combinations. Tests were conducted at an inlet-air reference velocity of 600 feet per second, inlet-air temperature of 1250° F, and combustor-inlet pressure of 15 inches of mercury absolute.

APPARATUS AND PROCEDURE

Two different test rigs were employed: (1) a 5- by 5-inch test section in which screening tests (stability data only) were conducted and (2) a 10- by 12-inch section in which both stability and combustion efficiency of the more promising combinations were determined. Practically all flameholders were tested with both air and stoichiometric fuel-air mixtures in the jets. Mixture flow rates were approximately 1 percent by weight of the total airflow rate. Injection pressures up to 70 pounds per square inch were used.

Except for the test sections, the test facilities were essentially the same as that described in reference 5. Preheating of the inlet air was accomplished by means of a single-can combustor located upstream of the main test section; the resulting vitiation of the combustion air thus closely simulated actual afterburner operation. Liquid JP-4 fuel was injected normal to the airstream through two spray bars located upstream of the flameholders (fig. 1(a)). Instrumentation, test procedures, and methods of calculation were similar to those described in reference 5.

RESULTS

5- By 5-Inch Test Section

The following combinations were investigated: single-orifice tubes injecting contrastream, multiple-orifice tubes injecting either contrastream or normal to the stream, and combinations of these jets with a $\frac{1}{2}$-inch or $1\frac{1}{2}$-inch wide horizontal V-gutter flameholder located upstream of the aerodynamic jets in which the distance between V-gutter and jets was also varied. Orifice diameters varied from 1/16 to 1/4 inch for the single-orifice tubes and from 0.020 inch to 0.031 inch for the multiple-orifice tubes.

No aerodynamic flameholder by itself was able to stabilize a flame at the desired test conditions. Large reductions in inlet-air velocity were necessary in order to obtain stable combustion with the aerodynamic flameholders only. When a $1\frac{1}{2}$-inch wide V-gutter (30 percent blockage) was installed upstream of the jets, stable combustion was obtained at the desired test conditions. Stability limits with the jet - V-gutter combination were somewhat wider than those with the V-gutter alone.

10- By 12-Inch Test Section

Since in the screening tests flame stabilization at an inlet-air velocity of 600 feet per second could not be accomplished with aerodynamic jets alone, the following jets were tested in combination with a V-gutter ($1\frac{1}{2}$-in. wide) flameholder of approximately 30 percent blocked area:

A - One row of seventy-eight 0.020-inch holes per bar

B - Two rows of seventy-eight 0.020-inch holes each per bar, rows at 90° to each other

C - One row of four 0.090-inch holes per bar

D - Five 0.90-inch to 0.125-inch-diameter expanding nozzles per bar

E - One row of six 0.166-inch holes per bar (this bar was designed for 5 percent injection).

The jet tubes were located 3 and 5 inches downstream from the open end of the V-gutter and injected upstream. Orientation of the V-gutter and tubes is shown in figure 1(b).

The results of the tests are presented in figure 2. Combustion efficiencies are plotted against total fuel-air ratio, including the fuel burned in the preheater. The results indicate that no gains in combustion efficiency over that obtained with the V-gutter flameholder alone were realized with the various air-jet combinations tested. Even with a jet-mixture flow equal to 5 percent of the total airflow, no significant increases in combustion efficiency were noted. In addition, no marked differences in blowout limits with variations in fuel-air ratio were observed.

SUMMARY OF RESULTS

From the tests conducted in the two test installations the following results were obtained:

1. At the conditions investigated, aerodynamic flameholders alone were unable to maintain a stable flame at injection pressures up to 70 pounds per square inch.

2. When used in combination with a good-design V-gutter flameholder, the aerodynamic jets did not increase combustion efficiency or improve combustor stability.

CONCLUDING REMARKS

The results suggest that with the limited flow rates and injection pressures that would be available from compressor-bleed air, aerodynamic flameholders alone will not provide a means of flame stabilization at the very severe inlet conditions often encountered in afterburner operation. Furthermore, although the addition of aerodynamic jets might improve the combustion efficiency and stability of a low-drag flameholder of marginal performance, no significant improvement in performance should be expected if jets are used in combination with an initially well-designed flameholder.

Lewis Research Center
National Aeronautics and Space Administration
Cleveland, Ohio, January 12, 1959

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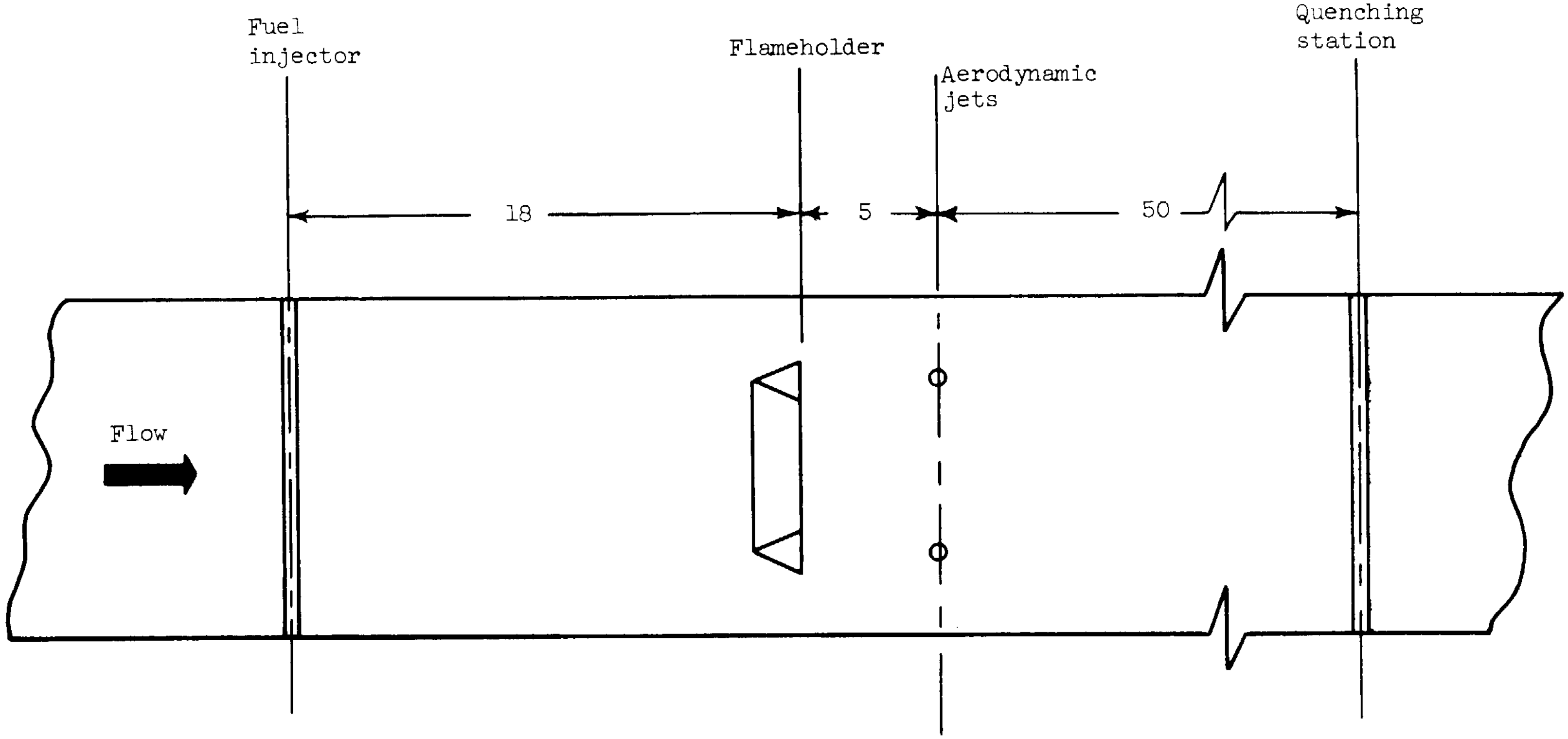
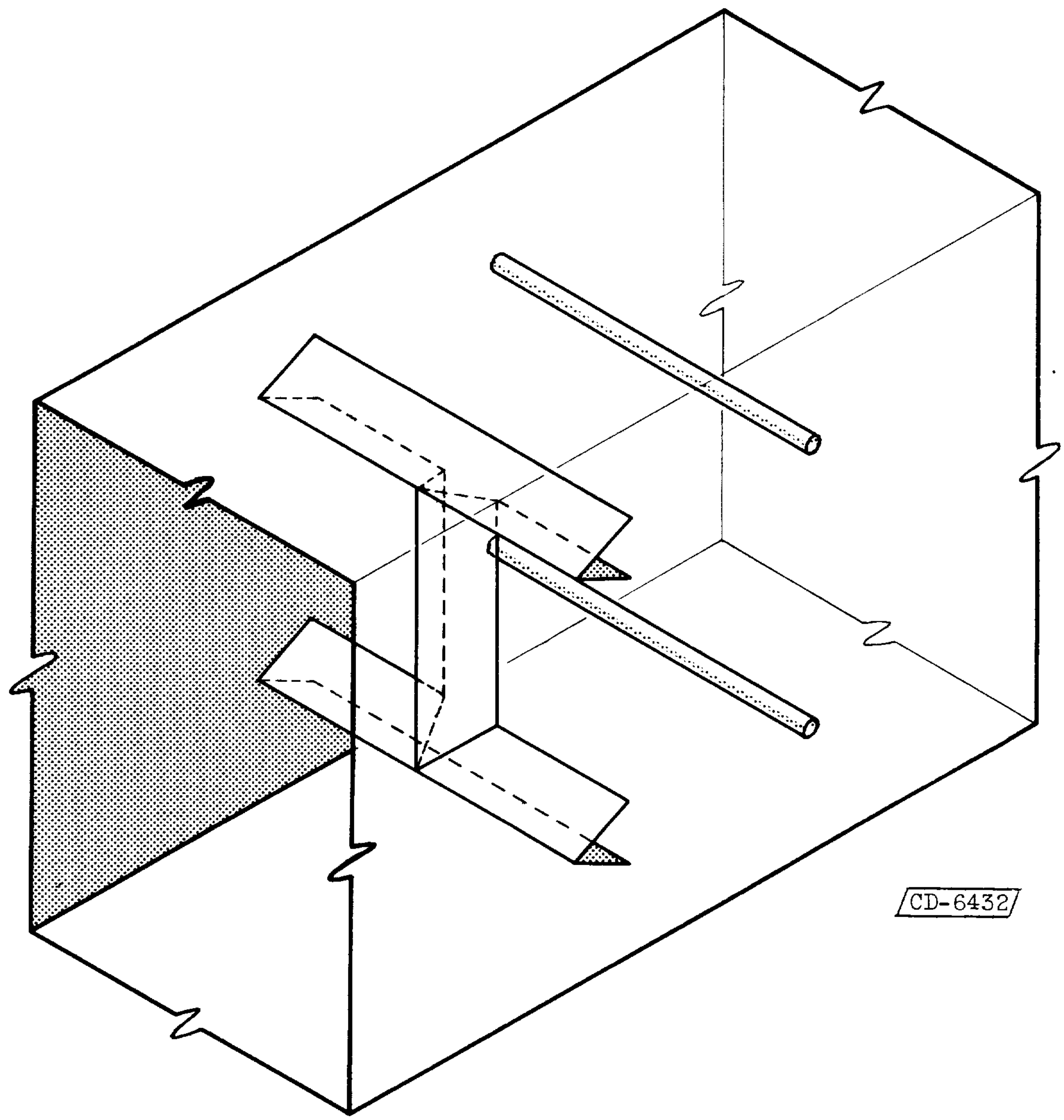


(a) Location of fuel-injection, flameholding, and flame-quenching stations. (Dimensions in inches.)

Figure 1. - Flameholder installation in 10- by 12-inch duct.



(b) Isometric view of V-gutter and aerodynamic jets.

Figure 1. - Concluded. Flameholder installation in 10- by 12 inch duct.

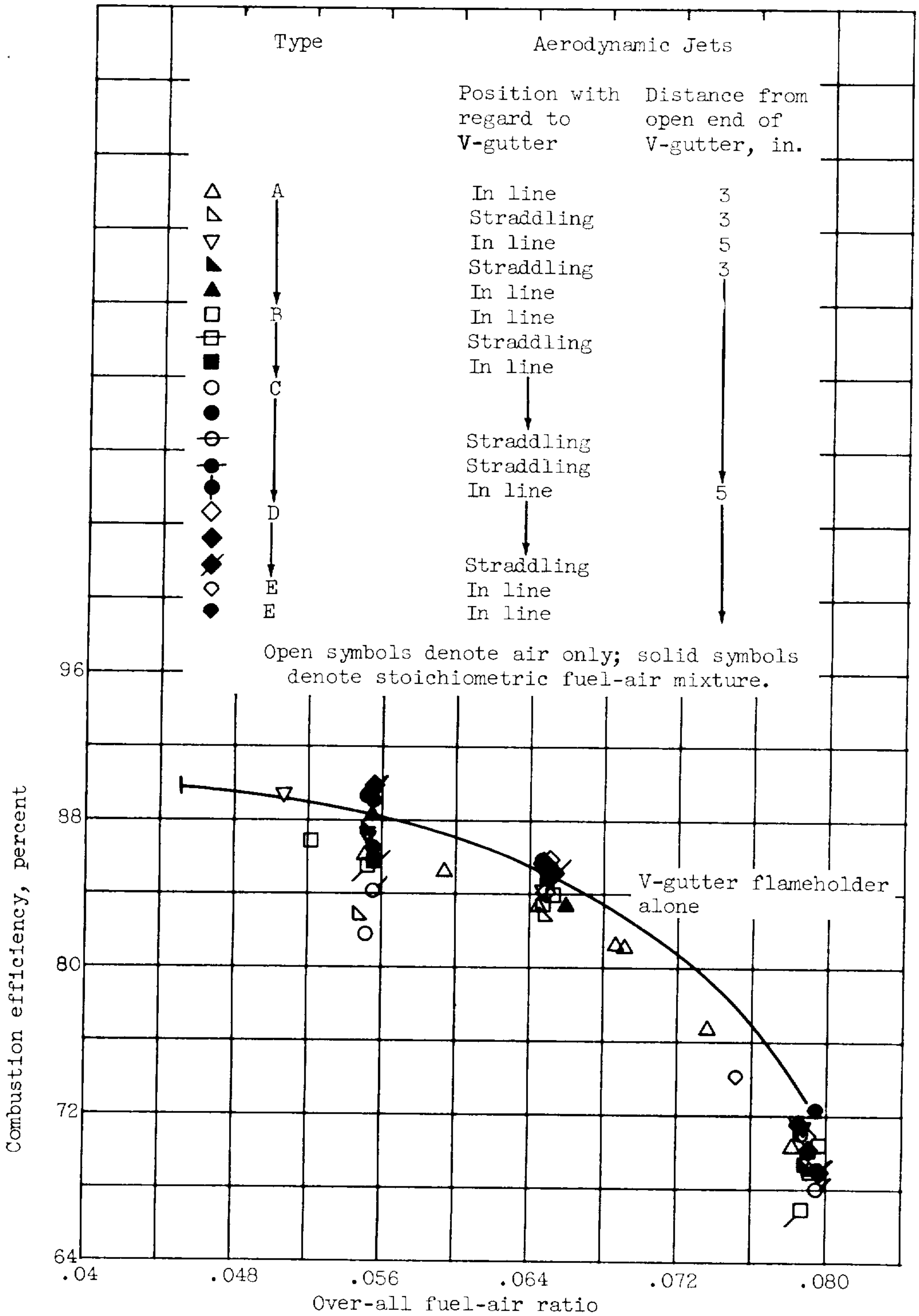


Figure 2. - Combustion efficiencies of V-gutter - aerodynamic-jet combinations. Inlet-air pressure, 15 inches of mercury absolute, inlet-air reference velocity, 600 feet per second, inlet-air temperature, 1250° F.

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The flame-holding capabilities of a number of aerodynamic jets and of combinations of these jets with a V-gutter flame holder were investigated at severe afterburner operating conditions. At an inlet-air velocity of 600 feet per second, no aerodynamic flame holder alone was able to maintain stable combustion at flow rates and injection pressures that would be available from compressor-bleed air. With various combinations of a V-gutter flame holder and aerodynamic jets, stable combustion was achieved at the velocity given; however, no improvement in combustion efficiency was obtained.

Copies obtainable from NASA, Washington

1. Engines, Turbojet (3.1.3)
2. Engines, Ram-Jet (3.1.7)
3. Combustion - Turbine Engines (3.5.2.2)
4. Combustion - Ram-Jet Engines (3.5.2.3)

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